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OREGON STATE UNIVERSITY

DEPARTMENT OF SOIL SCIENCE
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MEMORANDUM

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TO: Mr. Edward W. Crump, Technical Officer

FROM: Gerald H. Simonson, U-619, Oregon State University *GHS*
Co-Investigators: D. P. Paine, R. D. Lawrence, J. A. Norgren,
W. Y. Pyott, J. H. Herzog, R. J. Murray, and
R. Rogers

SUB: (E73-10770) MULTI-DISCIPLINE RESOURCE INVENTORY OF SOILS, VEGETATION AND GEOLOGY Progress Report, period ending 30 Jun. 1973 (Oregon State Univ.) 25 p
Ove: HC 12/25 CACL 08G G3/13 00770
N73-27246
Unclas

1. Use a multi-discipline team approach to determine features that can be successfully monitored by ERTS-A imagery for resource inventory, planning, land-use zoning and resource development.
2. Using carefully selected sample areas, develop a comprehensive resource inventory mapping system for use in planning, zoning, and resource development.

Summary:

During the present reporting period, Geology, Soil Science, and Rangeland Resources have continued acquisition of ground truth by mapping their respective subjects on NASA highflight imagery (72-114). Electrical Engineering, Rangeland Resources, and the Computer Center have cooperated on automatic classification of MSS digital data for selected sample sites within the study area. The forestry section has been primarily involved with a multi-stage timber survey of Ochoco National Forest. Geology and Soil Science have developed digital formats for their respective components of the Comprehensive Ecological Legend. A separate special report of a non-contract study on applications of ERTS Imagery for monitoring field burning in Western Oregon is being submitted with this report.

Multi-discipline Resource Inventory of Soils, Vegetation and Geology.

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Geology:

An important part of our ground truth and satellite imagery mapping effort in this project has been development of a computer compatible, digital legend that will embody a large portion of the geologic information significant for land use, which can be presented on a map base. Portions of such a legend have been previously presented in these progress reports. In this report a more complete scheme is included (Appendix A). This information is to be included in the denominator of the symbol as envisioned by Poulton. The emphasis in this legend is on moderate to large area mapping at relatively small scales (1:125,000 at present). The legend as presently developed is also intended for use particularly in photo-interpretation, and for practical land-use applications. Thus it attempts to emphasize those features directly interpretable from various kinds of remote sensing imagery; however, no effort has been made to derive a legend that is strictly photo-interpretable. Too much information would be omitted that is important to making land-planning decisions if such an approach had been taken. Much of this important data is available in existing publications and can be compiled on imagery that is being used at the same time that new information is being extracted from the imagery.

Geologic and landform mapping on the high flight imagery, for ground truth, is well underway. Discussion of the legend designed for this work and of examples of the results is included in Appendix A. Numerous faults and fractures can be mapped on the high-flight imagery. This work is in the initial stages but indicates that the numerous structures interpreted on the satellite imagery in the Ochoco frame (Figure 1) are probably real. On the high flight imagery many of the fractures can be confirmed as faults by observable disruption of bedding, offset topography, or other diagnostic features. An example of the results is attached. Of particular note is the large number of faults and fractures mapped in the area of the Clarno and John Day formations that have not previously been mapped.

Soil Science:

Mapping of soil associations on high flight imagery (NASA 72-114) for ground truth purposes is continuing. Approximately half of the study area (Crook County, Oregon) has been covered. During the next reporting period we expect to complete the ground truth phase of this project. A first approximation has been developed for the soils portion of the comprehensive ecological legend. This digital legend is intended to be computer compatible and consistent with the Soil Taxonomy System used by the Soil Conservation Service, U.S. Department of Agriculture (see Appendix B).

Forestry:

The major thrust of forestry research in the ERTS-1 project for the last reporting period has been towards the completion of the timber survey of the Ochoco National Forest. Using the new strata presented

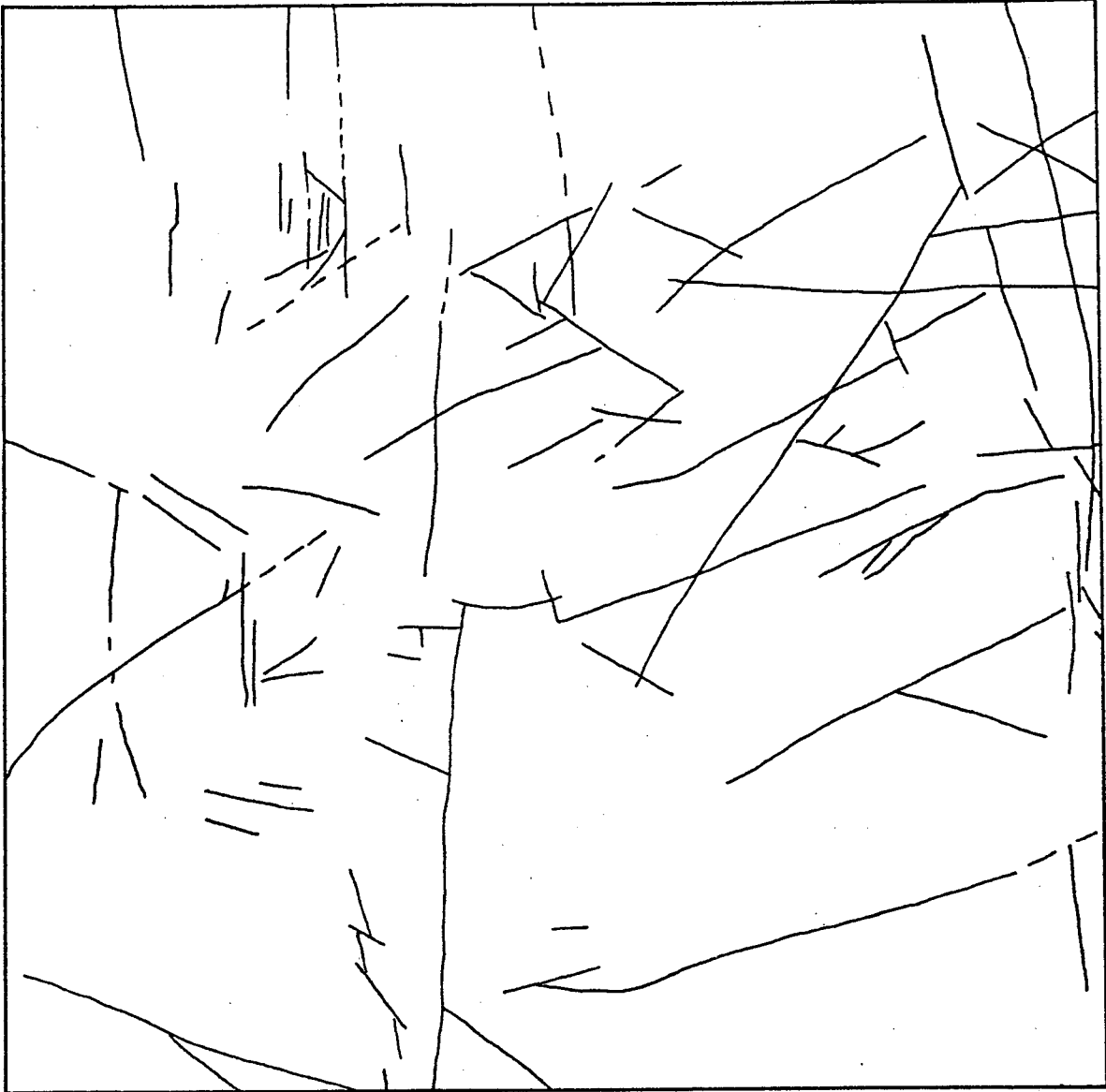


Figure 1
Faulting as mapped from frame 3183, flight 72-114

in the last report, twenty-five new plots of 20.25 acres were randomly located in each strata and measured for percent crown closure (%CC) and stand Height Class (HT) by three interpreters. Ten of these plots in each strata were then selected using Hartley's PPS sampling rule for further subsampling.

Each of these plots were divided into nine subplots of 2.25 acres and reinterpreted for %CC and HT by three interpreters. Again plots from these subplots were selected by the above sampling rule for further measurements. A computer program has been developed to convert the data into usable statistical form to allow statistical analysis.

Contracted photocoverage of the last subsample has been received and interpretation will begin shortly. The contract photocoverage was taken with a new Zeiss 12" camera on Kodak Aeronegative film and both color transparencies and black and white prints were obtained. These products appear to be excellent for their intended use.

During the next reporting period, photo-interpretation of the final photo stage of the multi-stage sampling design will be completed. Field data acquisition is expected to begin about mid-July and should be completed by the first of August.

A preliminary study has been made of the analysis of clearcuts from ERTS MSS color composites. Initial evaluation appears to suggest that clearcuts can be categorized into three broad classes based on vegetative cover. These three classes are bare soil, brush regeneration, and timber regeneration. A more detailed study is being prepared during the present reporting period to include analysis by size and ownership as well as vegetative cover. A comparison with the results from digital data will also be conducted with the PIXEL facilities and the computer center.

Rangeland Resources:

Work is continuing on mapping vegetation of Crook County at 1:120,000 (from NASA highflight imagery, 72-114). Intensity of delineation was not maximized for the detail of that scale. The mapping was more generalized, eliminating very fine details and complexing intermixed and closely associated, similar vegetation types. This intensity was used to synthesize the information in a form which would be more compatible as a ground truth base for smaller scale imagery such as the ERTS-1 at scales of 1:250,000 and 1:1,000,000.

The mapping was done on color prints using every other photo and using a mirror stereoscope. This required mapping of 27 photos. The time spent in mapping ranged from 15 minutes to 2 hours and 20 minutes per photo and required a total of 45 hours. The great variance in mapping time per photo was due to the small amount of area mapped on those photos which were on the periphery of the Crook County area and complexity of vegetation from area to area.

Completion of the narrative map legend is in progress. Some field checking to confirm identification of map delineations remains to be done.

Progress has been made in classifying vegetation through the use of computer analysis of the MSS digital data. However, problems have been encountered in trying to use training sets from one date for other dates of imagery, even though no appreciable phenological change in the vegetation had occurred. Classification errors greater than in the original date occurred in the multi-date application.

A computer classification using multi-spectral information was made of the Big Summit Prairie area vegetation. The classification was based on training sets that were selected from within the classification area. The most accurate results were obtained using 10 classes and opening the threshold on each class so that each data resolution element was classified.

Electrical and Computer Engineering:

The PIXEL Laboratory in close cooperation with Rangeland Resources specialists involved in our interdisciplinary ERTS-1 project has obtained significant results in computer classification of natural vegetation in the vicinity of Big Summit Prairie, Crook, County, Oregon.

Vegetation of the area was stratified into four shrub types, four forest types, three wet meadow types, and water. Impure training sets representing these types were then selected from within the area to be classified.

The automatic classification problem is burdened by two major considerations not normally encountered in classification of agricultural vegetation.

Non-homogeneity

Natural plant communities seldom have the abrupt demarcation lines associated with agricultural vegetation. Since vegetation is often non-homogeneous it is difficult to get "pure" samples for use in training our automatic classifier.

Geologic considerations

The region around Big Summit Prairie contains changes in elevation from a maximum of 5000 feet to a minimum of 4500 feet. The sloping land tends to affect the reflection characteristics of the vegetation. Volcanic activity in the area leads to a wide variety of soil types and textures. In natural vegetation communities the vegetation is strongly affected by the soil type and available moisture.

The Classifier:

The features used in this investigation were the data magnitudes provided by the ERTS multispectral scanner. This gave a four element vector for each ground resolution element. No normalizing was done to the vectors. It was later noted that some improvement in the data could be achieved by correcting for gain differences in the sensors on the satellite. Because of the large amount of data these corrections were not made.

A phototype vector was constructed for each of the classes indicated above. Each element of the prototype vector was the mean of the corresponding training set for that class.

Classification of unknown feature vectors was performed based on the euclidian distance between the unknown vector and each of the prototype vectors. Classification was determined by the smallest distance. A threshold distance was included to allow a "none of these" classification, if the distance was larger than expected for a given class.

Vegetation classification by computer was compared with independent classification based on ground exploration and low-altitude aerial photography. Very close agreement was obtained using the two methods.

A more complete report of this investigation, with illustrations, will be included in the next progress report.

Significant Results:

The following significant results have been determined during this reporting period:

1. Computer classification of natural vegetation, in the vicinity of Big Summit Prairie, Crook County, Oregon was carried out using MSS digital data. Impure training sets, representing eleven vegetation types plus water, were selected from within the area to be classified.
2. Close correlations were visually observed between vegetation types mapped from the large scale photos (1:30,000, 24" focal length, NASA Flight 72-134, 7 August) and the computer classification of the ERTS data (Frame #1021-18151, 13 August 1972). Separable types are pine/fescue (Pinus ponderosa with Festuca idahoensis), moist meadow (Carex, Juncus spp.), silver sagebrush (Artemisia cana), low sagebrush scablands (A. arbuscula and A. rigida) and water (reservoirs). No quantitative assessment of classification accuracy has been made pending further ground checks.

In addition to work performed on the primary study area, extensive geologic investigation of ERTS-1 imagery for the entire state of Oregon has resulted in finding a number of features that are well recorded on the imagery. These significant results are listed below along with examples of the results.

3. Numerous linear features (lineaments) have been mapped on ERTS imagery of the state. In the basin and range province of the southeastern portion of the state, these linears are mainly faults of relatively small displacement that are already well known. The pattern produced by lineament mapping on ERTS imagery is essentially similar to that produced by many other investigators. However, numerous lineaments can be mapped on ERTS imagery in other portions of the state. In particular, MSS-7 is a useful band in forested regions. On this band the disturbing pattern of clear cuts is less intrusive than on others and the topography is clearly displayed. Linear elements are readily interpreted. Examples of this kind of mapping from three frames are attached (Figures 2, 3, & 4). These are for the Mt. Jefferson, Crater Lake, and Ochoco areas, respectively, 1041-18265-7, 1041-18271-7, and 1004-18210-7.

The origin of the features mapped and the reproducibility of the patterns are serious questions as yet. Preliminary studies of reproducibility are disturbing. They show that while the overall pattern is usually similar, different observers draw different numbers of lines and locate their lines in different places. Generally 1/3 to 1/2 of the lines are identical. These statements relate primarily to lineament mapping on forested areas. Much better results are obtained on the open desert. The features mapped are natural in origin, generally reflecting topographic alignments. Probably many of them are fracture controlled, that is, result from erosion along joints and/or faults. If this is true, it implies that much more topography in maturely eroded areas is structurally controlled than has been thought heretofore. However, such structures have not been mapped in the areas under discussion because of the heavy soil and vegetation cover and it is difficult to conceive of a means of confirming the interpretation.

4. Mapping in the Klamath Mountains of southwestern Oregon has demonstrated the ability to distinguish the peridotite and serpentinite masses from other rocks by the lack of vigor of the vegetation on the peridotite masses. A map illustrating this result is attached (Figure 5).
5. The cuesta of the Elkton Syncline, in the Tyee Sandstone at the southern end of the Coast Range, is clearly displayed on MSS-7 of frame 1276-18240-7. The same structure is not interpretable on band 5. A map showing this result is attached (Figure 7).
6. A new structure is strikingly revealed on a color reconstitution of frame 1004-18212-4,5,7 recently received from NASA. It is associated with Walker Rim northeast of Crater Lake. The

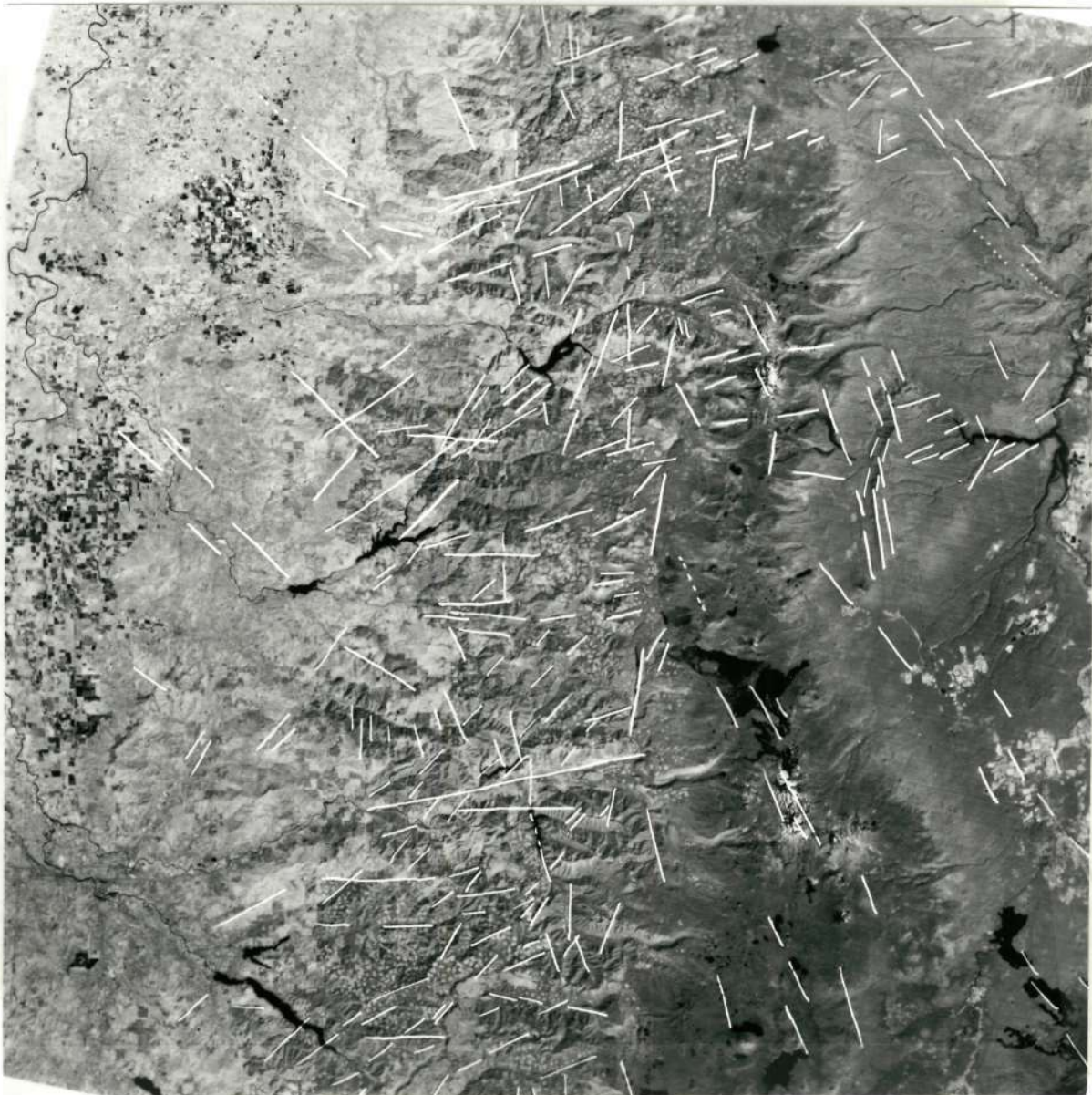


Figure 2
Lineaments mapped on the Mt. Jefferson Frame, MSS-7

1041-18265-7



Figure 3
Lineaments mapped on the Crater Lake Frame, MSS-7

1041-18271-7

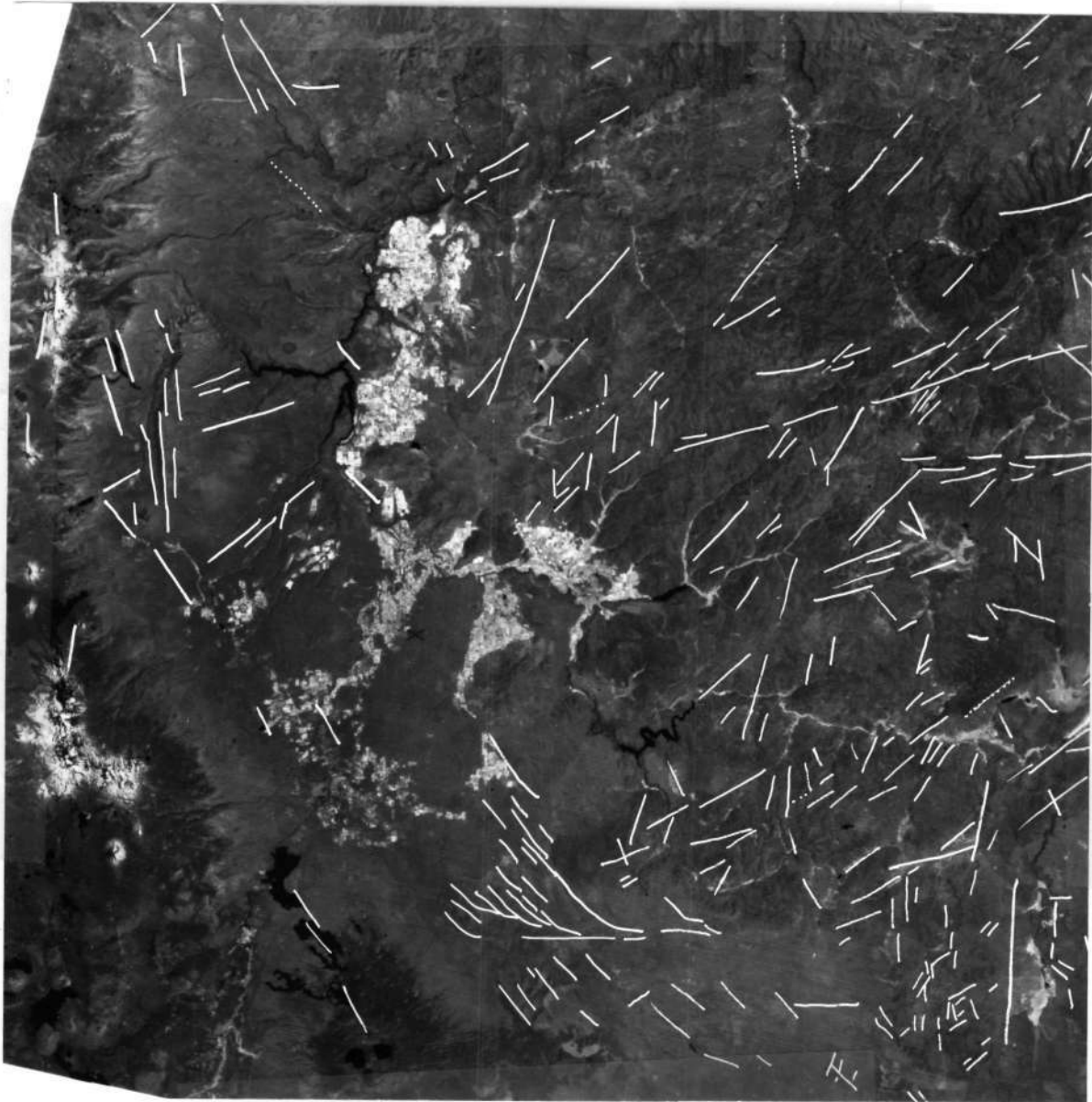


Figure 4

Lineaments mapped on the Ochoco frame, MSS-7

1004-18210-7

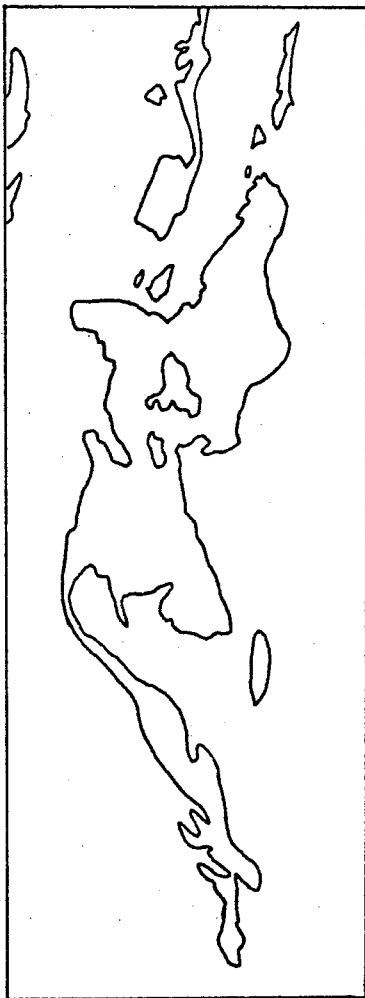


Figure 5
Josephine Peridotite Body
as mapped on frame
1041-18274-5.

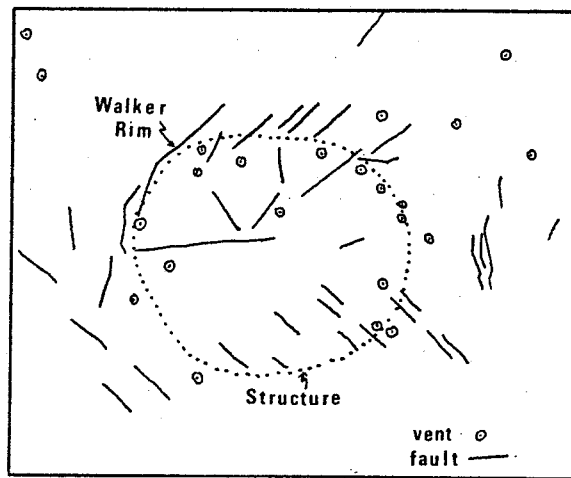


Figure 6
Unknown structure associated with
Walker Rim on frame 1004-18212-4,5,7

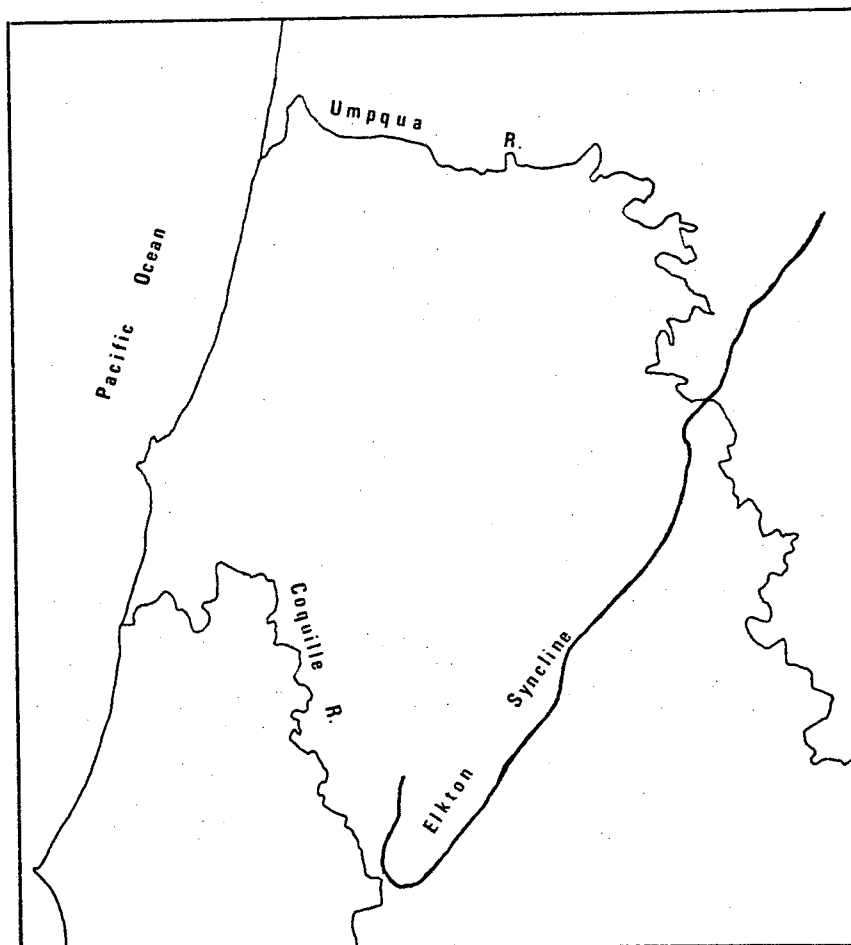


Figure 7
Elkton Syncline in the Tyee Sandstone as mapped
on MSS-7 of frame 1276-18340.

structure is roughly circular in pattern and is associated with considerable fracturing. As revealed on the ERTS image the structure is made up on volcanic vents in the circular pattern, probably on somewhat higher ground. A few vents are present in the interior of the structure. The vents retain their constructional features topographically indicating that the feature is of relatively recent origin. A very preliminary interpretation would be to suggest that some sort of ring dike system was expressed at the surface by this structure. A map of the structure is attached (Figure 6).

GHS:lw

cc: ERTS Contracting Officer, Code 245
ERTS Project Scientist, Code 650
ERTS Scientific Monitor
J. H. Boeckel, Code 430

APPENDIX A

GEOLOGY AND LANDFORM PORTION OF A DIGITAL LEGEND

Work on a computer compatible, digital legend that will embody a large portion of the significant landuse information that can be presented on a map base has been an important part of our ground truth and satellite imagery mapping effort in this project. Portions of such a legend have been previously presented, following an older approach developed by Poulton and others (1971), which attempt to represent three major categories of information. These are (1) landform description, including quantitative data, (2) landform genesis, and (3) bedrock material. In this report a more complete scheme is included which overcomes numerous weaknesses of previous approaches. This information is to be included in the denominator of the symbol as envisioned by Poulton. The emphasis in this legend is on moderate to large area mapping at relatively small scales (1:125,000 at present). For smaller areas a much more detailed legend would be needed which would excessively increase the digital presentation in the present format. The legend developed is also intended for use particularly in photo-interpretation, and for practical land-use applications. Thus it attempts to emphasize those features directly interpretable from various kinds of remote sensing imagery; however, no effort has been made to derive a legend that is strictly photo-interpretable. Too much information would be unrepresented that is important to land planning decision making if such an approach had been taken. Much of this important data is available in existing publications and can be compiled on imagery that is being used at the same time that new information is being extracted from the imagery.

The digital format that we have developed is in the following format:

1 2 . 3 4 . 5 6 7

where,

- 1 = Major descriptive landform class
- 2 = Minor descriptive landform class
- 3 = Slope class
- 4 = Aspect
- 5 = Major material class
- 6 = Minor material class
- 7 = Material type

Thus there are three groupings of seven symbols. The first is of two hierarchial symbols which describe the landforms. These are readily photo-interpretable and another digit could be added if any reason existed. The second set of symbols is non-hierarchial, and is more quantitative than the first set and also deals with landforms. Again the categories are readily interpreted from imagery. This set is separated from the first group by a decimal point so that a slope class can always be presented, no matter how many descriptive digits are

- 2 -

presented, without any confusion. The last group of symbols is again hierarchial. Both information on landform genesis and bedrock type are included in this group. These are only partially photo interpretable, largely because geologic information is so genetic in character. Several different materials may on occasion have very nearly identical or completely identical photo-appearances, but their different origins may have important practical consequences. Frequently the extent of a unit may be outlined from information contained in the imagery, but the identity must be established independently. The legend takes much of this information into account.

The following general comments apply to the individual symbols:

(1) The first symbol is derived from the set of terms and definitions previously used for "macrorelief". The term applied is based on relief and slopes within the area in question. Strictly speaking deviation from hierarchial organization is present in order to conserve on the number of symbols; that is, while "0" stands for undifferentiated flat lands, "1" and "2" separate out two categories of flat lands. This ploy is repeated for rolling lands.

(2) The minor descriptive landform class is new. We have tried to pick out landform features of particular importance to planning problems. Thus we have particularly looked at drainage density and pattern since these determine the degree of topographic irregularity within a major class. In the legend we have distinguished "dendritic" patterns from "parallel patterns because in the latter case engineering projects will encounter difficulty in one direction instead of in general.

(3) The slope angle classes allow more precise distinctions than the major descriptive category.

(4) The aspect class is new, and not regularly used. But in at least some cases it makes an important difference to the use of a land area to know that it is generally west facing or some such. When this symbol is missing it may be taken as indicating that no aspect dominates.

(5) The initial material category separates unconsolidated from consolidated materials. It further breaks these categories down according to the thickness of the unconsolidated material or the depth of weathering of the consolidated materials. Considerable flexibility enters here for the treatment of some materials. For example, depending on the importance attached to each a deeply weathered hilly area could be classed as thin unconsolidated and thus subdivided into various slope material classes or as deeply weathered consolidated and then subdivided according to bedrock types. As yet no means for showing layered structure is available, but this is a problem for all mapping methods.

(6) Where symbol "5" is unconsolidated, this category separates major genetic landform materials. Where symbol "5" is consolidated, this category separates major rock types, also by genesis. In the latter case the order is from soft to hard rock types.

(7) Details of the above categories of "6" are distinguished in this symbol.

NOTE: In categories "2", "6", and "7" the digit 9 is always reserved for undifferentiated or mixed classes. This is especially important in the material classes where specific mixtures will almost always have to be defined for the particular area under study. That is, the digit 9 of class "6" gives one nine different possibilities for special, local classes. An example might be 692 = shallow weathered consolidated materials: sandstones, tuffaceous sandstones, tuffs, and welded tuffs.

The digital legend in detail is attached as an appendix.

Typical examples of symbols developed from this legend are

(1) 56.22.012

This symbol would indicate an area of uniformly rolling land with an irregular surface pattern, which is identified as a landslide more than 10' thick. Surface slopes are 15-30% and the slope faces to the northeast.

(2) 65.26.603

This symbol would indicate an area with a rolling surface formed by the dip slope of a poorly consolidated conglomerate with shallow weathering (6" to 10'). The surface is incised by channels with a parallel pattern. It has 15-30% slopes and faces to the southeast.

(3) 8.8.999

This symbol indicates a mountainous area with slopes 0-100+% and no significant aspect. The material is unknown and requires ground investigation.

Geology and Landform Portion of the Digital Legend

Descriptive classes, (two digits)

- 1 = major descriptive class
- 2 = minor descriptive class

0- Flat lands (0-10% slopes, 0-10' local relief)

- 00 with smooth microrelief
- 01 with rough microrelief
- 09 Mixed or undifferentiated

1- Uniformly flat lands

- 10 Smooth with no significant microrelief
- 11 Smooth with little microrelief, low drainage density, dendritic drainage pattern
- 12 Smooth with little microrelief, low drainage density, parallel drainage pattern
- 13 With moderate microrelief in mounds, biscuits, or other patterned ground
- 14 Rough with intricate, non-integrated microrelief, very low drainage density, and no pattern.
- 15 Rough with integrated microrelief, moderate drainage density, and dendritic pattern
- 16 Rough with integrated microrelief, moderate drainage density, and parallel pattern
- 17 Smooth with moderate drainage density, and dendritic drainage pattern
- 18 Smooth with moderate drainage density, and parallel drainage pattern
- 19 Mixed or undifferentiated

2- Incised flatlands

- 20 Smooth with dendritic drainage patterns to incised channels
- 21 Smooth with parallel drainage patterns to incised channels
- 22 Showing patterned ground and dendritic pattern to incised channels
- 23 Showing patterned ground and parallel pattern to incised channels
- 24 Rough with dendritic drainage patterns to incised channels
- 25 Rough with parallel drainage patterns to incised channels

- 29 Mixed or undifferentiated

- 3- Sloping lands (10-30% local slopes, 0-10' local relief, significant regional slope)
 - 30 Smooth with little or no drainage pattern
 - 31 Smooth with drainage parallel to the regional slope
 - 32 Smooth with patterned ground, especially stone stripes
 - 33 With irregular rough microrelief
 - 34 Incised with deeper drainage parallel to regional slope
 - 35 Broken with local breaks that cross the regional slope (fault scarps, etc.)
 - 36 Dip slopes (stripped structural surfaces)
- 39 Mixed or undifferentiated sloping lands
- 4- Rolling lands (10-30% slopes, 10-100" local relief)
 - 40 With low to moderate drainage density and dendritic drainage pattern
 - 41 With high drainage density and dendritic drainage pattern
 - 42 With low to moderate drainage density and parallel drainage pattern
 - 43 With high drainage density
 - 44 With irregular surface pattern (landslide topography)
- 49 Mixed or undifferentiated rolling lands
- 5- Uniformly rolling lands
 - 50 With low drainage density and dendritic drainage pattern
 - 51 With moderate drainage density and dendritic drainage pattern
 - 52 With high drainage density and dendritic drainage pattern
 - 53 With low drainage density and parallel drainage pattern
 - 54 With moderate drainage density and parallel drainage pattern
 - 55 With high drainage density and parallel drainage pattern
 - 56 With irregular surface pattern (landslide topography)
 - 57 Dip slopes (stripped structural surfaces)
- 59 Mixed or undifferentiated
- 6- Incised rolling lands
 - 60 With low to moderate drainage density and dendritic pattern to incised channels
 - 61 With moderate to high drainage density and dendritic pattern to incised channels
 - 62 With low to moderate drainage density and parallel pattern to incised channels
 - 63 With moderate to high drainage density and parallel pattern to incised channels

- 64 Dip slopes (stripped structural surfaces) with dendritic pattern to incised channels
- 65 Dip slopes (stripped structural surfaces) with parallel pattern to incised channels

69 Mixed or undifferentiated

7- Hilly lands (10-50% slopes, 100-1000' local relief)

- 70 With low to moderate drainage density and dendritic drainage pattern
- 71 With high drainage density and dendritic drainage pattern
- 72 With low to moderate drainage density and parallel drainage pattern
- 73 With high drainage density and parallel drainage density
- 74 Incised with deeper drainage in dendritic pattern
- 75 Incised with deeper drainage in parallel pattern
- 76 With irregular surface pattern (landslide topography)

79 Mixed or undifferentiated

8- Mountainous lands (10-100+% slopes, more than 1000' local relief)

- 80 With low to moderate drainage density and dendritic drainage pattern
- 81 With high drainage density and dendritic drainage pattern
- 82 With low to moderate drainage density and parallel drainage pattern
- 83 With high drainage density and parallel drainage pattern

89 Mixed or undifferentiated

9- Escarpments and Canyons

- 90 Linear Escarpments
- 91 Irregular escarpments
- 92 Fault scarps of fault-line scarps
- 93 Antidip slopes
- 94 Canyons
- 95 Undrained depressions (e.g., sinkholes, kettles)

Slope and Aspect (two digits)

- 3 = Slope
- 4 = Aspect

Slope angle classes

0	0-5%
1	5-15%
2	15-30%
3	30-50%
4	50-100%
5	over 100%
6	0-30%
7	0-50%
8	0-100+%
9	15-50%

Aspect classes

0	No significant aspect (absent = 0)
1	North facing
2	Northeast facing
3	Northwest facing
4	East facing
5	West facing
6	Southeast facing
7	Southwest facing
8	South facing

Material Classes (three digits)

5 = Major material class
 6 = Minor material class
 7 = Material type

0	Thick unconsolidated materials (more than 10')
1	Thin unconsolidated materials (less than 10')
2	
3	
4	Unknown thickness unconsolidated materials

The classes "0" to "4" above use the following subclasses

0 Valley and plain materials

00	Floodplain alluvium
01	Terrace alluvium
02	Bajada and alluvial fan gravels
03	Fine clastics, muds
04	Medium clastics, sands
05	Coarse clastics, gravels
06	Mudflow and lahar deposits

09 Mixed or undifferentiated

1 Valley side materials

- 10 Saprolite
- 11 Colluvium
- 12 Landslide materials
- 13 Talus and scree
- 14 Solifluction deposits

19 Mixed or undifferentiated2 Lake and marine materials

- 20 Lake beds
- 21 Evaporite and playa deposits
- 22 Deltaic sands and muds
- 23 Estuarine sands and muds
- 24 Beach, bar, and spit sands
- 25 Marine sands and muds
- 26 Beach gravels
- 27 Marine gravels

29 Mixed or undifferentiated3 Aeolian materials

- 30 Pumice and air fall ash
- 31 Sand dunes, hills, plains
- 32 Loess

39 Mixed or undifferentiated4 Glacial materials

- 40 End moraine
- 41 Ice-contact gravels (eskers, kames, etc.)
- 42 Ground moraine

49 Mixed or undifferentiated

- 5 Deeply weathered consolidated materials (greater than 10')
- 6 Shallow weathered consolidated materials (6" to 10')
- 7 Little weathered consolidated materials (less than 6")
- 8
- 9 Consolidated materials with unknown depth of weathering

The classes "5" to "9" above use the following subclasses

0 Clastic Sedimentary rocks

- 00 Siltstones and mudstones
- 01 Shales
- 02 Poorly consolidated sandstones
- 03 Poorly consolidated conglomerates
- 04 Well consolidated sandstones
- 05 Well consolidated conglomerates

09 Mixed or undifferentiated1 Non-clastic sedimentary rocks

- 10 Gypsum and anhydrite
- 11 Halite and evaporites
- 12 Poorly consolidated limestone
- 13 Well consolidated limestone
- 14 Dolomite
- 15 Mixed carbonates
- 16 Chert

19 Mixed or undifferentiated2 Intermediate volcanic rocks

- 20 Fragmental, including pyroclastics, breccias, and non-welded tuffs
- 21 vent rocks
- 22 Flows
- 23 Welded tuffs
- 24 Mixed fragmental and flow rocks.
- 25 Dikes, sills, and other shallow intrusives

29 Mixed or undifferentiated3 Silicic volcanic rocks

- 30 Fragmental, including pyroclastics, breccias, and non-welded tuffs
- 31 Vent rocks, domes
- 32 Flows
- 33 Welded Tuffs
- 34 Mixed fragmental and flow rocks
- 35 Dikes, sills, and other shallow intrusives

39 Mixed or undifferentiated

4 Basaltic volcanic rocks

- 40 Vent rocks (commonly cinder cones)
- 41 Fragmental, including breccias, etc.
- 42 Basalt flows
- 43 Mixed fragmental and flow rocks
- 44 Dikes, sills, and other shallow intrusives

49 Mixed or undifferentiated5 Mixed volcanic rocks

- 50 Fragmental
- 51 Flows
- 52 Shallow intrusives
- 53 Vents

59 Mixed or undifferentiated6 Coarse-grained intrusive rocks

- 60 Serpentinite
- 61 Ultramafic rocks, often including serpentinites
- 62 Mafic intrusives
- 63 Intermediate intrusives
- 64 Silicic intrusives
- 65 Pegmatite

69 Mixed or undifferentiated7 Metamorphic rocks

- 70 Slates and phyllites
- 71 Schists
- 72 Metavolcanics (Greenstones and Greenshists, blueschists)
- 73 Marbles
- 74 Hornfels
- 75 Gneisses, migmatites, granulites
- 76 Quartzites
- 77

79 Mixed or undifferentiated9 Combined units (defined for each specific problem except "99")

- 90 Mixed silicic and intermediate volcanic materials
(specifically undifferentiated John Day and Clarno)
- 91 Basalt flows and thin alluvium, mixed

99 Unknown, but photo-identified, unit that needs field checked

24

APPENDIX B

Soil Characteristics

The digits used to denote these four categories occupy four spaces immediately to the right of those discussed in Appendix A.

This version of the soils portion of the Comprehensive Ecological Legend is designed primarily for application to the present study area (Crook Co., Ore.)

<u>Depth</u>	<u>Texture, of control section or Bt horizon</u>	<u>Drainage and reaction</u>	<u>Soil climate and epipedon</u>
1. very deep, >60"	1. sandy skeletal	1. excessive	1. aridic, ochric, mesic
2. deep, 40-60"	2. loamy skeletal	2. good	2. " , " , frigid
3. mod. deep, 20-40"	3. clayey skeletal	3. mod. good	3. xeric, mollic, mesic
4. shallow, 10-20"	4. sandy	4. somewhat poor	4. " , " , frigid
5. very shallow, <10"	5. coarse loamy	5. poor	5. xeric, ochric, frigid
6. rock land	6. fine loamy	6. very poor	6. xeric, pachic, mesic
7. mod. deep to hardpan	7. coarse silty	7. peat and muck	7. " , " , frigid
8. shallow to hardpan	8. fine silty	8. alkaline	8. xeric, cumulic, mesic
9. shallow to soft rock	9. fine	9. strongly alkaline	9. " , " , frigid
0. shallow to gravel	0. very fine	0. very strongly alkaline	0. xeric, mollic, cryic